W. F. Uhl.

REPORT ON A TEST-TRIAL

OF A

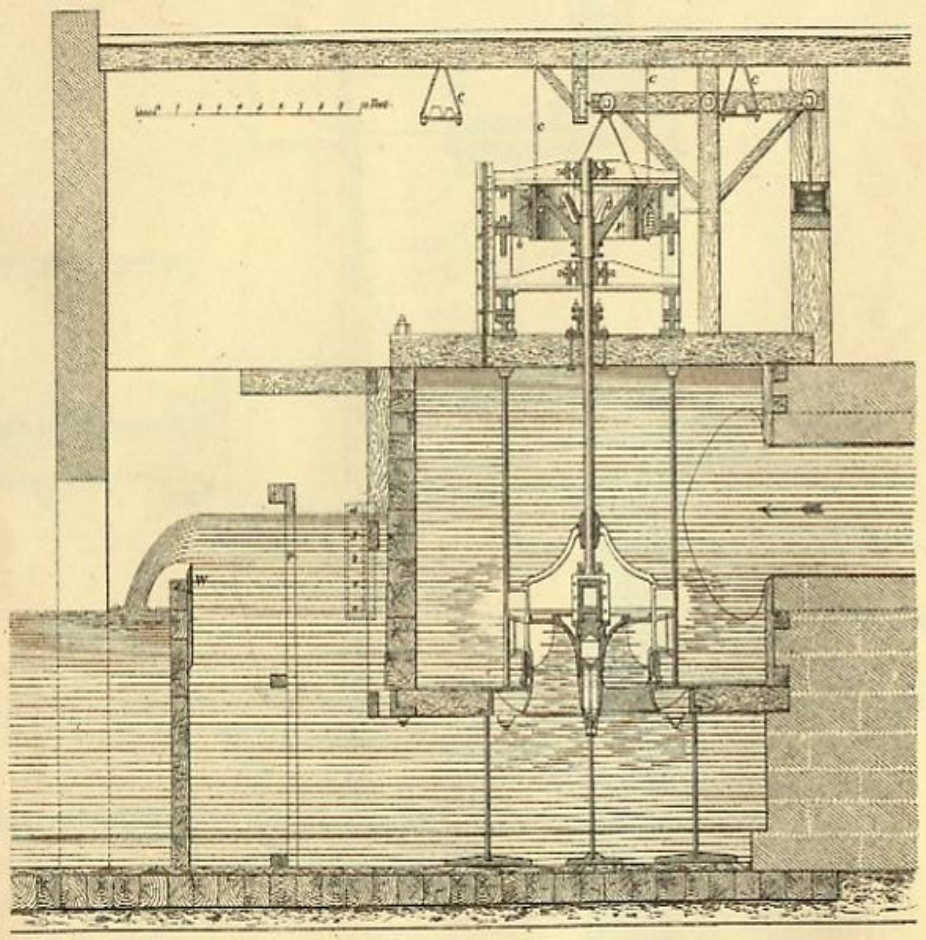
Swain Turbine Water Wheel.

BY

James B. Francis, C. E., of Lowell.

Reprinted from the *Journal of the Franklin Institute*, April, 1875.

PHILADELPHIA:
WM. P. KILDARE, PRINTER, 734 & 736 SANSOM STREET.
1875.



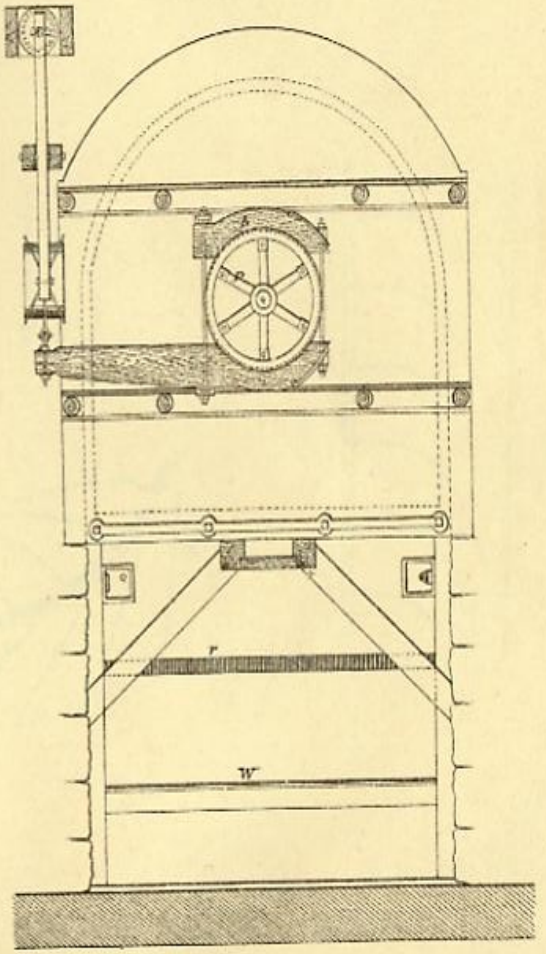
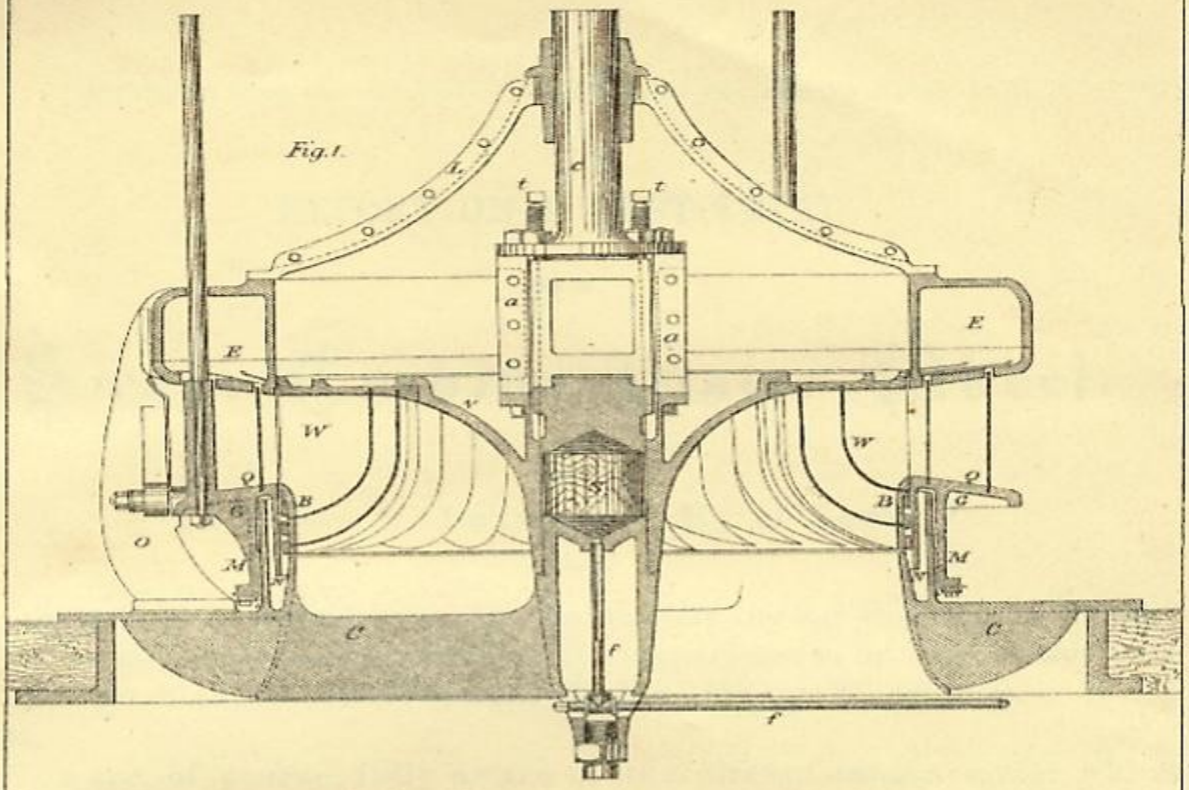

W

Fig. 1.



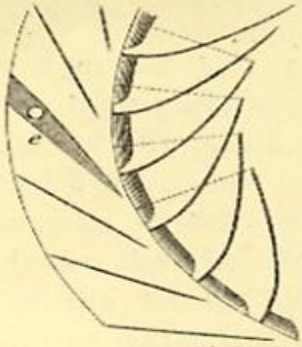


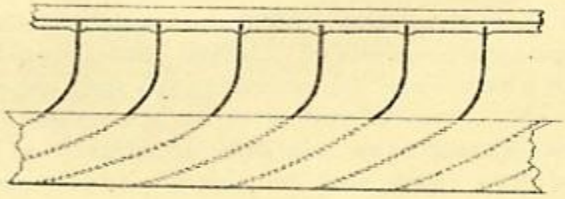
Fig. 2.

SWAIN TURBINE COMPANY'S

72 INCH WHEEL

SCALE OF FEET

Fig. 3



Lith. Longacre & Co. Phila.

[Reprinted from the *Journal of the Franklin Institute* for April, 1875.]

REPORT ON A TEST-TRIAL

OF A

Swain Turbine Water Wheel.

By James B. Francis, C. E., of Lowell.*

Dear Sir:—I send you, on the accompanying sheets, the principal data and computed results of the experiments on the Power and Discharge of the Westerly Swain Turbine Water Wheel in your No. 5 Mill.

You are, of course, fully aware of the circumstances under which these experiments were made, but as a matter of record I will briefly describe them.

During the last summer you put in a pair of Swain Turbines, seventy-two inches in diameter, and of about 330 horse-power each, on 18 feet fall; both of the same pattern; in place of the Centre-vent Wheels that had been in use in the same mill since it was built, in 1849; and it became necessary, for the purpose of gauging the quantity of water drawn by the Boott Cotton Mills from the canals of the Proprietors of the Locks and Canals on Merrimack River, to ascertain the quantity of water discharged by them at different heights of speed-gate, and with different speeds. For this purpose a gauging weir was constructed below the Westerly wheel, over which all the

[* The Report on the Swain Turbine here given, was made to A. G. Cumnock, Esq., Agent of the Boott Cotton Mills, Lowell, Mass. In the note accompanying the manuscript sent us, the author states that the experiments were made with great care, the necessary apparatus being constructed at considerable cost. He also states that the makers of the Turbine had nothing to do with the experiments, and bore no part of the expense; they must therefore be considered free from any bias in favor of the makers.—Ed.]

about 0 2 feet. The crest of the weir was 12·08 feet above the bottom of the race-way. The depth on the weir was observed by means of a hook-gauge, placed in a tight box on the upper side of the rack, which communicated by means of a lead pipe 0·75 inch in diameter with the space between the rack and the weir; the lower part of the pipe being placed an inch or two above the floor of the wheel-pit, in the angle formed by the floor and the weir, where there is the least motion in the water; the lower end being closed, and the communication maintained by means of holes in said lower part of the pipe, one-eighth inch diameter, one foot apart. The water had a free fall from the weir, the height of the water on the down-stream side of the weir, being in no experiment less than 2·5 feet below the top of the weir. The fall acting on the wheel was observed by noting the height of the water in the wheel-pit and the head in the penstock, substantially as in the experiments of 1849, above referred to. The box containing the gauge for observing the height in the wheel-pit, communicated with the wheel-pit, by means of a lead pipe 0·75 inch in diameter, placed in the angle formed by the floor and wall of the pit, pierced with holes one-eighth inch diameter, about one foot apart. The brake was of oak, the long arm having an effective length of 10·760 feet, which was increased by the unequal lengths of the arms of the bell-crank to $10{\cdot}760 \times \frac{5{\cdot}000}{4{\cdot}495} = 11{\cdot}969$ feet.

The weight of the brake was . . .	3228·75	pounds.
" " friction pulley, . .	5025·00	"
	8253·75	"

The friction pulley takes the place of a bevel gear weighing 2440 pounds. The difference between the weight of the brake and friction pulley and the bevel gear, viz., 5813·75 pounds, was counterbalanced by a combination of suspension rods, levers and weights, which left the same weight on the step on which the wheel runs, during the experiments, as in the ordinary running of the wheel. The counterbalance relieves the step of the extra weight, by means of the brake lifting against the upper flange of the friction pulley.

The weights used were mostly pieces of pig iron of various weights, which were marked upon them by the City Sealer of Weights and

TABLE II.

Coefficients of Useful Effect for several heights of Speed Gate, and Velocities of wheel, deduced from the Experiments made on the Seventy-two inch Swain Turbine Water Wheel, in Boott Cotton Mill No. 5, in August, 1874.

Height of opening of Speed Gate, Inches.	Coefficients of Useful Effect; the Ratio of the Velocity of the Exterior Circumference of the wheel to the Velocity due the head acting on the wheel, being as given in the headings of the several columns.																				
	0·60	0·61	0·62	0·63	0·64	0·65	0·66	0·67	0·68	0·69	0·70	0·71	0·72	0·73	0·74	0·75	0·76	0·77	0·78	0·79	0·80
13·08 Full Gate	0·785	0·771	0·776	0·782	0·788	0·793	0·798	0·803	0·808	0·813	0·818	0·822	0·827	0·830	0·832	0·834	0·835	0·835	0·834	0·833	0·831
12·00	0·775	0·781	0·786	0·791	0·796	0·802	0·807	0·811	0·816	0·820	0·824	0·828	0·832	0·835	0·837	0·838	0·839	0·838	0·837	0.835	0·831
11·00	0·775	0.781	0·786	0·792	0·797	0·802	0·807	0·812	0·817	0·821	0·825	0·829	0·831	0·833	0·833	0·832	0·830	0·827	0·824	0·819	0·815
10·00	0·782	0·788	0·794	0·800	0·805	0·810	0·815	0·820	0·824	0·828	0·831	0·833	0·834	0·834	0·833	0·831	0·828	0·824	0·820	0·814	0·809
9·00	0·779	0·785	0·791	0·797	0·803	0·808	0·812	0·816	0·820	0·823	0·825	0·827	0·828	0·827	0·825	0·823	0·820	0·815	0·811	0·806	0·800
8·00	0·771	0·777	0·783	0·788	0·793	0·797	0·800	0·802	0·804	0·805	0·806	0·807	0·806	0·805	0·803	0·800	0·798	0·795	0·791	0·788	0·783
7·00	0·764	0·769	0·774	0·778	0·781	0·784	0·787	0·788	0·790	0·790	0·790	0·790	0·788	0.786	0·783	0·780	0·777	0·772	0·768	0·763	0·757
6·00	0.742	0·747	0·751	0·754	0·757	0·759	0·760	0·761	0·761	0·760	0·759	0 758	0·756	0·753	0·751	0·747	0·743	0·739	0·734	0·728	0·722
5·00	0·708	0·711	0.714	0·717	0·719	0·721	0·722	0·722	0·721	0·720	0·719	0·718	0·717	0·715	0·713	0·710	0·707	0·704	0·701	0·697	0·693
4·00	0·654	0·658	0·661	0·664	0·666	0·668	0·669	0·669	0·668	0·667	0·665	0·663	0·660	0·657	0·655	0·652	0·648	0·645	0·641	0·637	0·633
3·00	0·576	0·579	0·581	0·583	0·585	0·586	0·586	0·586	0·585	0·584	0·582	0·580	0·578	0·575	0·571	0·568	0·563	0·559	0·555	0·550	0·545
2·00	0·474	0·474	0·473	0·472	0·471	0·469	0·466	0·463	0·460	0·456	0·451	0·446	0·441	0·434	0·428	0·420	0·412	0·404	0·395	0·385	0·375

Measures. As a check, the weights in the scale were frequently taken out and weighed in a mass on platform scales. The bell-crank, which formed the scale-beam, was balanced when there was no weight in the scale.

The floor and walls of the wheel-pit were water-tight. The leakage at the weir, if any, was too small to be taken account of.

The experiments detailed on the accompanying sheets, marked Table I, I think require little explanation beyond what is contained in the headings of the several columns. You will observe that they are not in all cases given in the order in which they were made. The first twenty-two experiments were intended to be a preliminary trial, to ascertain if the testing apparatus operated satisfactorily. When they were made it was supposed that the full opening of the speed-gate was 13·00 inches, and they were intended to be made at quarter, half, and full gate. It was subsequently ascertained that the full opening was 13.08 inches. The remaining experiments were made with special reference to determining the quantity of water discharged at each full inch in height of opening of the speed-gate, from two to twelve inches, and when fully open.

The experiments have been plotted on section paper, and a series of curves drawn for the several heights of gate, for the purpose of interpolation and eliminating irregularities.

Table II has been de luced from these curves; it indicates that from 9 inch gate to 13·08 inch gate, or say from about two-thirds gate to full gate, the maximum coefficient of useful effect varies from 0·828 to 0·839, or about one per cent.; the velocity of the exterior circumference of the wheel relatively to the velocity due the head, corresponding to the maximum coefficient of useful effect, being for 9 inch gate about 0·720, and for full gate about 0·765. At half gate the maximum coefficient of useful effect is about 0·78, at a relative velocity of about 0.68. At one-quarter gate, the maximum coefficient of useful effect is about 0 61 at a relative velocity of about 0·66.

Very respectfully,

[Signed] JAMES B. FRANCIS.

Lowell, Mass., Feb. 24, 1875.

APPENDIX.

DESCRIPTION OF THE SEVENTY-TWO INCH SWAIN TURBINE WATER WHEEL BUILT BY THE SWAIN TURBINE CO., LOWELL, MASS., EXPERIMENTED UPON AT THE BOOTT COTTON MILLS, AUGUST 3–7, 1874.

Plate I represents a vertical section through the centre of the wheel and pit, showing the measuring weir w, and the rack r, and also parts of the weighing apparatus, friction pulley p, brake b, and counterbalancing apparatus c c c c.

Plate II represents a plan of the weighing apparatus and measuring flume with weir and rack.

Plate III represents a vertical section through the centre of the wheel, on a larger scale, with a plan of portions of the wheel and gate, and a development of the outer surface of the wheel.

The lower curb C, is a strong disc of cast iron, with a short cylinder upon which the gate moves, and an inner tube with diverging sides, through which the water leaving the wheel is discharged into the pit. There are three arms reaching from the sides of this tube to the hub which forms the pintle upon which the wheel revolves. The step S is a cylinder of white oak, with conical ends, and is free to

...n the wheel or to remain stationary upon the pintle while
...wheel revolves around it. By means of pipe (*f*) water is supplied
...e step, passing through its centre and escaping outward over its
. The intermediate piece a a connecting the shaft c and the
...l coupling v, can be removed to replace the step, without disturb-
...either the wheel or shaft. The screws t t in the flange of the
..., are used to adjust the wheel vertically.

...e gate G was made with two cylinders, N and M, attached at
... tops to a disc Q, which forms an angle of 80° with the cylinders.
...he lower end of the outer cylinder is a narrow flange to which is
...ned the leather packing, which prevents the escape of water

between the gate and the lower curb. This gate has 24 guides, 3 of them being of cast iron, and of the form shown in the plan at e, Plate III. The other guides, 21 in number, are of bronze 0·23 inch in thickness and 18·94 inches long. These are sharpened at each end to 0·04 inch in thickness, with a bevel on each side one inch long; and are so set as to form an angle of 14° with the tangent to the wheel passing through their inner edges.

Outside of, and in a line with, the thick guides, are placed three stands, one of which is seen at o, Fig. 1, Plate III. These support the chamber E, and the wheel cover L. The lower disc of this chamber is slotted, so that the guides may enter the chamber when the gate is raised, by means of the hoisting rods which pass through the thick guides. The plates represent the gate fully opened. The gate is opened by lowering, and closed by raising it, so that when the gate is first opened, the water is admitted into the wheel, immediately under the crown, and the depth of the section of the stream passing through the guides, is increased in proportion as the gate is opened. The lower edge of the chamber, and the upper edge of the gate, are finished so as to form a close joint when brought into contact. The inner edges of the guides are 1⅝ inches distant, radially, from the outer edges of the buckets.

The wheel W, is 72 inches in diameter at the outer edges of the buckets, and 23·35 inches in depth from the under side of crown to the lower edge of the band. It has 25 buckets of bronze, these being formed between dies in a press, and having the crown plate and the lower band cast upon them of iron.

Fig. 2, Plate III, is a horizontal section just below the crown plate, and represents the form of the bucket for the first six inches below the crown.

Fig. 3 is a development of a portion of the cylindrical surface of the wheel containing the outer edges of the buckets. The discharging edge of the bucket lies in a vertical plane passing through the axis of the wheel, and is parallel to this axis, from the under side of the crown, to a point about 8½ inches below it, and from this point is continued in the form of a quadrant having a radius equal to one-fifth of the diameter of the wheel, and having its centre in the cylinder forming the outer circumference of the wheel. Thus forming, in connection with the surface of the adjoining bucket, an outlet

which is in effect a union of two wheels, an inward discharge, and a downward discharge.

The following measurements were made at the mill, before the wheel was started:

Vertical distance from under side of crown to the lower edge of the buckets,	23·35	inches.
Vertical distance from the under side of crown to the top of band B,	13·285	"
Total area of outlets of wheel (25 in number),	9·558	square feet.
Vertical movement of speed gate,	13·08	inches.
Mean shortest distance from the inner edge of one guide to side of adjacent guide (24 in number),	4·532	"
Total area of inlet in speed gate,	9·880	square feet.

THE JOURNAL

OF THE

FRANKLIN INSTITUTE,

Devoted to Science and the Mechanic Arts.

ESTABLISHED 1826.

The Journal of the Franklin Institute is issued in monthly numbers of seventy-two pages each. Its object is not only to encourage original research in all matters relating to the practical applications of science, more especially to Engineering, both Civil and Mechanical, by the publication of memoirs, but also to furnish to the members of the Institute and to its readers generally, a review of current discovery and invention, not only by the re-publication of valuable articles in extenso, but also by a monthly summary of novelties in Science and the Arts.

Subscription Price $5.00 per Annum.

Letters on business should be addressed to the Actuary of the Franklin Institute. Communications for the Journal to the Editor.

The Journal can also be obtained from

DAVID G. FRANCIS, New York.
JOHN WILEY & SON, " - "
D. VAN NOSTRAND, " "
L. W. SCHMIDT, " "
W. C. LITTLE & CO., Albany, New York.
LITTLE, BROWN & CO., Boston, Mass.
A. WILLIAMS & CO., " "
WHITFORD & RICE, Lawrence. "
THE WESTERN NEWS CO. Chicago, Illinois.
MOHUN & BESTOR, Washington, District of Columbia.

Also from

HECTOR BOSSANGE & Son, 11 Quai Voltaire, Paris.
EIVES & ALLEN, King William Street, London,

Who are authorized to receive subscriptions and to make exchanges for periodicals devoted to the arts and sciences.

TABL

Experiments on the Power of, and Quantity of Water discharged by the Westerly Seventy-

No. of the experim't	Date, 1874.	Temperature		Height of the Regulating gate.	TIME.						Duration of the experim't.	Total number of revolutions of the wheel during the experiment.	Weight in the Scale.	Useful effect, or the friction of the brake.	Total fall acting upon the wheel.
		Of air in wheel room.	Of water in wheel pit.		Beginning of the experiment.			Ending of the Experiment.						Pounds raised one foot per Second.	
		Deg. Fahr.	Deg. Fahr.	Inches.	Hours.	Min.	Sec.	Hours.	Min.	Sec.	Seconds.		Pounds Avoir.		Feet.
1	Aug. 1, A. M.			3·25	9	17	6·5	9	23	47·5	401·0	450	434·56	36673·8	13·963
2	" "			"	9	37	2·0	9	46	57·0	595·0	650	459·56	37755·2	13·967
3	" "	75	73·5	"	9	55	55·5	10	7	54·0	718·5	750	484·56	38038·2	13·912
4	" "			"	10	11	48·5	10	21	28·5	580·0	550	534·56	38121·4	13·928
5	" "			"	10	27	27·0	10	34	29·0	422·0	350	584·56	36460·5	13·930
6	" "			"	10	40	9·0	10	46	57·0	408·0	500	385·56	35533·6	13·934
7	" "			6·50	11	10	0·5	11	17	33·5	453·0	600	646·00	64346·3	13·365
8	" "			"	11	20	8·5	11	29	7·0	538·5	650	768·87	69794·0	13·276
9	" "			"	11	31	15·0	11	39	8·5	473·5	550	824·47	72020·4	13·306
10	" "			"	11	41	19·0	11	50	7·0	528·0	600	849·47	72594·4	13·273
11	Aug. 1, P. M.			"	1	59	27·5	2	8	23·5	536·0	600	874·47	73615·5	13·287
12	" "			"	2	9	55·0	2	19	4·5	549·5	600	899·47	73859·8	13·286
13	" "			"	2	25	17·5	2	34	38·5	561·0	600	924·47	74356·5	13·283
14	" "			"	2	36	13·0	2	47	19·5	666·5	700	949·47	74992·3	13·316
15	" "			"	2	58	57·5	3	6	43·5	466·0	400	1074·47	69359·5	13·249
16	" "			13·00	3	23	16.0	3	27	45·0	269·0	500			13·291
17	" "			"	3	33	41·5	3	44	8·5	627·0	800	1074·47	103099·0	12·685
18	" "			"	3	50	26·0	3	58	54·0	508·0	600	1213·22	107761·8	12·712
19	" "		73	"	4	1	7·0	4	10	52·0	585·0	650	1290·22	107810·0	12·666
20	" "			"	4	13	8·5	4	24	32·0	683·5	750	1315·22	108532·3	12·703
21	" "			"	4	29	19·0	4	36	30·5	431·5	450	1365·22	107071·1	12·716
22	" "			"	4	40	9·5	4	49	7·0	537·5	450	1514·47	95352·6	12·579
23	Aug. 4, P. M.			2·00	5	12	9·5	5	23	4·5	655·0	950	90·00	9816·6	14·312
24	" "			"	5	25	26·5	5	31	58·0	391·5	550	115·00	12149·7	14·309
25	" "			"	5	32	34·0	5	41	18·5	524·5	700	148·69	14923·6	14·324
26	" "			"	5	44	32·0	5	51	5·0	393·0	500	173·69	16618·4	14·279
27	" "			"	5	51	46.0	5	57	54·5	368·5	450	198·69	18246·9	14·288
28	" "			"	5	58	37·5	6	5	4·5	387·0	450	223·69	19560·8	14·342
29	" "			"	6	8	23·5	6	20	47·5	744·0	750	284·56	21572·5	14·283
30	Aug. 5, A. M.			"	7	38	42·5	7	47	19·0	516·5	500	294·56	21444·3	14·228
31	" "			"	7	48	19·5	7	57	30·5	551·0	450	344·56	21162·3	14·190
32	" "		70·5	3·00	8	8	22·5	8	16	33·5	491·0	400	528·72	32392·3	13·979
33	" "			"	8	18	17·5	8	26	42·5	505·0	500	464·69	34600·3	13·973
34	" "			"	8	29	7·0	8	37	2·0	475·0	500	439·69	34806·5	13·977
35	" "			"	8	39	20·0	8	45	24·5	364·5	400	414·69	34223·5	13·972
36	" "			"	8	46	8·5	8	54	8·0	479·5	550	389·69	33614·9	13·960
37	" "			"	8	56	56·0	9	3	53·0	417·0	500	364·69	32884·8	13·988
38	" "			"	9	5	54·0	9	12	36·0	402·0	500	339 69	31773·5	14·026
39	" "			"	9	14	28·0	9	23	40·0	552·0	750	281·00	28712·2	14·011
40	" "			"	9	25	59·5	9	30	37·5	278·0	400	231·00	24995·7	14·049
41	" "		70·5	4·00	9	42	35·0	9	48	34·0	359·0	550	231·00	26614·5	13·899
42	" "			"	9	51	23·5	9	55	57·5	274·0	400	298·81	32805·2	13·853
43	" "			"	9	57	9·5	10	2	33·5	324·0	450	367·00	38332·9	13·812
44	" "			"	10	3	51·5	10	10	20·5	389·0	500	443·81	42899·8	13·782
45	" "			"	10	11	43·0	10	19	18·5	455·5	550	496·94	45124·9	13·764
46	" "			"	10	20	1·0	10	27	51·0	470·0	550	521·94	45932·8	13·741
47	" "			"	10	29	18·5	10	36	41·0	442·5	500	546·94	46476·6	13·703
48	" "			"	10	37	27·0	10	43	31·5	364·5	400	571·94	47201·0	13·703
49	" "			"	10	45	9·5	10	52	31·0	441·5	450	621·94	47672 5	13·699
50	" "			5·00	11	15	43·0	11	24	10·5	507·5	550	713·31	58135·7	13·440
51	" "			"	11	24	59·0	11	30	42·0	343·0	350	771·19	59179·7	13·482
52	" "			"	11	33	21·5	11	40	27·5	426·0	400	828·34	58492·0	13·444
53	" "			"	11	41	27·5	11	42	29·5	62·0	50	887·03	53796·5	13·436
54	Aug. 5, P. M.			"	2	44	11·5	2	50	50·0	398·5	350	862·03	56937·7	13·483
55	" "			"	3	2	7·0	3	9	29·5	442·5	500	680·62	57836·1	13·479
56	" "			"	3	10	13·0	3	18	48·5	515·5	600	655·62	57386·9	13·542
57	" "			"	3	19	30·5	3	26	30.5	420·0	500	630·62	56458·1	13·546
58	" "			"	3	27	50·5	3	35	9·0	438·5	550	580·62	54767·5	13·552
59	" "			"	3	36	25·0	3	43	16·0	411·0	550	505·62	50884·2	13·589
60	" "			"	3	44	59·0	3	51	49·0	410·0	600	370·12	40733·1	13·660
61	" "			6·00	4	4	51·0	4	10	21·5	330·5	500	369·56	42045·7	13·539
62	" "			"	4	11	29·5	4	18	22·5	413·0	600	446·37	48767·9	13·518
63	" "			"	4	19	34·0	4	26	50·0	436·0	600	539·56	55839·6	13·458
64	" "			"	4	28	7·0	4	36	2·0	475·0	600	656·94	62405.3	13·381
65	" "			"	4	37	25·0	4	44	22·0	417·0	500	720·97	65011·3	13·307
66	" "			"	4	45	5·0	4	53	1·5	476·5	550	774·09	67193·8	13·355
67	" "		70·5	"	4	53	46·0	5	2	38·5	532·5	600	799·09	67711·9	13·315
68	" "			"	5	3	23·0	5	10	11·0	408·0	450	824·09	68354·1	13·314
69	" "			"	5	10	58·5	5	17	24·5	386·0	400	888·78	69263·5	13·281
70	" "			"	5	19	5·5	5	26	46·5	461·0	450	945·94	69440·5	13·291
71	" "			"	5	47	30·0	5	53	6·0	336·0	300	995·94	66873·3	13·291
72	Aug. 6, A. M.		70·0	7·00	7	37	42·0	7	46	26·0	524·0	800	408·59	46912·0	13·390
73	" "			"	7	47	34·5	7	55	12·5	458·0	650	547·91	58478·3	13·333
74	" "			"	7	56	27·5	8	4	10·0	462·5	600	699·91	68284·1	13·199
75	" "			"	8	5	31·5	8	12	25 5	414·0	500	807·16	73310·7	13·164
76	" "			"	8	13	8·5	8	21	7·5	479·0	550	875·34	75586·1	13·142
77	" "			"	8	22	36·0	8	29	59·5	443·5	500	900·34	76334·5	13·126
78	" "			"	8	31	30·0	8	39	47·5	497·5	550	925·34	76932·3	13·102
79	" "			"	8	41	20·5	8	49	58·0	517.5	550	975·34	77955·4	13·144
80	" "			"	8	51	37·5	9	0	50·0					

ABLE I.

Seventy-Two Inch Swain Turbine Water Wheel, in Boott Cotton Mill, No. 5, at Lowell, Mass.

Total fall acting upon the wheel.	Depth of water on the weir.	Quantity of water passing the weir.	Weight of a Cubic Foot of water.	Total power of the water.	Ratio of the useful effect to the Power expended.	Ratio of the velocity of the exterior circumference of the wheel to the velocity due the fall acting on the wheel.	Quantity of water which passed the wheel, reduced to a uniform fall of 17 feet.	REMARKS.
Feet.	Feet.	Cubic feet per Second.	Pounds.	Pounds raised one foot per Second.			Cubic feet per Second.	
13·963	1·1940	70·865	62·245	61590·6	0·5954	0·7064	78·193	
13·967	1·1993	71·337	"	62018·9	0·6088	0·6876	78·703	
13·912	1·2025	71·623	"	62022·1	0·6133	0·6583	79·174	
13·928	1·2089	72·196	"	62589·8	0·6091	0·5977	79·761	Speed Gate open one quarter, nearly.
13·930	1·2122	72·491	"	62855·3	0·5801	0·5227	80·082	
13·934	1·1791	69·543	"	60315·8	0·5891	0·7722	76·813	
13·365	1·5823	108·108	"	89935·6	0·7155	0·8522	121·926	
13·276	1·6157	111·549	"	92180·2	0·7571	0·7792	126·228	
13·306	1·6296	112·992	"	93583·3	0·7696	0·7490	127·717	
13·273	1·6340	113·450	"	93729·5	0·7745	0·7337	128·393	
13·287	1·6437	114·461	62·249	94671·2	0·7776	0·7224	129·470	Speed Gate open one half, nearly.
13·286	1·6485	114·963	"	95079·3	0·7768	0·7046	130·043	
13·283	1·6535	115·486	"	95490·4	0·7787	0·6903	130·649	
13·316	1·6596	116·126	"	96257·8	0·7791	0·6770	131·210	
13·249	1·6641	116·599	"	96163·3	0·7213	0·5547	132·077	
13·291	1·6616	116·336	"	96250·8		1·1993	131·572	Brake loose on friction pulley.
12·685	2·0618	160·803	"	126974·8	0·8120	0·8427	186·140	
12·712	2·0862	163·666	"	129510·5	0·8321	0·7792	189·268	
12·666	2·0983	165·092	"	130166·2	0·8282	0·7344	191·263	
12·703	2·1037	165·730	"	131050·7	0·8282	0·7242	191·722	Speed Gate fully open, nearly.
12·716	2·1074	166·167	"	131531·0	0·8140	0·6879	192·130	
12·579	2·1015	165·470	"	129567·9	0·7359	0·5553	192·362	
14·312	0·9143	47·485	62·272	42320·5	0·2320	0·9018	51·753	
14·309	0·9207	47·985	"	42756·7	0·2842	0·8736	52·302	
14·324	0·9297	48·690	"	43430·6	0·3436	0·8295	53·043	
14·279	0·9363	49·209	"	43756·0	0·3798	0·7920	53·694	
14·288	0·9403	49·525	"	44064·5	0·4141	0·7599	54·021	
14·342	0·9474	50·087	"	44732·9	0·4373	0·7222	54·531	
14·283	0·9611	51·177	"	45518·7	0·4739	0·6274	55·833	
14·228	0·9616	51·217	62·268	45375·9	0·4726	0·6037	55·985	
14·190	0·9673	51·673	"	45657·7	0·4635	0·5100	56·559	
13·979	1·1701	68·748	"	59841·2	0·5413	0·5125	75·813	
13·973	1·1653	68·325	"	59447·8	0·5820	0·6230	75·363	
13·977	1·1617	68·009	"	59189·5	0·5881	0·6623	75·004	
13·972	1·1569	67·588	"	58802·0	0·5820	0·6906	74·553	
13·960	1·1502	67·002	"	58241·8	0·5772	0·7221	73·938	
13·988	1·1445	66·504	"	57925·4	0·5677	0·7541	73·315	
14·026	1·1377	65·912	"	57565·9	0·5519	0·7812	72·564	
14·011	1·1196	64·346	"	56137·5	0·5115	0·8538	70·878	
14·049	1·1051	63·100	"	55199·8	0·4528	0·9030	69·411	
13·899	1·2152	72·761	"	62971·6	0·4226	0·9666	80·469	
13·853	1·2430	75·272	"	64929·2	0·5052	0·9226	83·384	
13·812	1·2646	77·242	"	66431·8	0·5770	0·8791	85·694	
13·782	1·2918	79·748	"	68437·6	0·6268	0·8144	88·570	
13·764	1·3106	81·495	"	69845·7	0·6461	0·7656	90·570	
13·741	1·3168	82·074	"	70224·3	0·6541	0·7426	91·289	
13·703	1·3213	82·495	"	70389·4	0·6603	0·7180	91·885	
13·703	1·3272	83·048	"	70861·4	0·6661	0·6973	92·501	
13·699	1·3362	83·894	"	71562·5	0·6662	0·6478	93·457	
13·440	1·4706	96·865	"	81064·5	0·7172	0·6954	108·941	
13·482	1·4764	97·736	"	82048·8	0·7213	0·6537	109·749	
13·444	1·4882	98·609	"	82548·7	0·7086	0·6024	110·886	
13·436	1·4803	97·825	"	81843·5	0·6573	0·5175	110·037	
13·483	1·4846	98·251	"	82487·9	0·6903	0·5626	110·324	
13·479	1·4613	95·948	"	80529·8	0·7182	0·7239	107·753	
13·542	1·4578	95·603	"	80615·6	0·7119	0·7440	107·116	
13·546	1·4502	94·856	"	80009·7	0·7056	0·7608	106·264	
13·552	1·4370	93·564	"	78954·8	0·6937	0·8014	104·793	
13·589	1·4131	91·240	"	77203·4	0·6591	0·8539	102·050	
13·660	1·3674	86·850	"	73872·7	0·5514	0·9314	96·887	
13·539	1·4531	95·141	"	80208·3	0·5242	0·9671	106·610	
13·518	1·4843	98·222	"	82677·0	0·5899	0·9294	110·148	
13·458	1·5167	101·455	"	85019·7	0·6568	0·8824	114·027	
13·381	1·5513	104·947	"	87442·4	0·7137	0·8123	118·290	
13·307	1·5657	106·411	"	88172·4	0·7373	0·7732	120·274	
13·355	1·5795	107·821	"	89662·9	0·7494	0·7429	121·648	
13·315	1·5834	108·221	"	89725·7	0·7547	0·7263	122·283	
13·314	1·5890	108·795	"	90195·3	0·7578	0·7110	122·936	
13·281	1·6016	110·092	"	91044·1	0·7608	0·6689	124·556	
13·291	1·6127	111·239	"	92061·4	0·7543	0·6298	125·806	
13·291	1·6089	110·846	"	91736·3	0·7290	0·5761	125·361	
13·390	1·5379	103·590	62·272	86375·4	0·5431	0·9814	116·722	
13·333	1·5889	108·785	"	90321·4	0·6474	0·9142	122·837	
13·199	1·6369	113·752	"	93495·7	0·7303	0·8399	129·096	
13·164	1·6652	116·714	"	95676·5	0·7662	0·7830	132·634	
13·142	1·6817	118·453	"	96939·7	0·7797	0·7450	134·723	
13·126	1·6859	118·897	"	97184·7	0·7855	0·7320	135·310	
13·102	1·6894	119·268	"	97309·2	0·7906	0·7184	135·856	
13·144	1·7014	120·541	"	98663 1	0·7901	0·6896	137·087	
13·088	1·7110	121·563	"	99075·4	0·7870	0·6575	138·544	

Other Information

TURBINES,

THEORETICAL AND PRACTICAL,

WITH NUMERICAL EXAMPLES AND EXPERIMENTAL RESULTS AND MANY ILLUSTRATIONS.

DE VOLSON WOOD,

Professor of Mechanical Engineering, Stevens Institute of Technology.

SECOND EDITION,
REVISED AND ENLARGED.

J. WILEY & SONS,
NEW YORK.

1896

NEW YORK PUBLIC LIBRARY

68. *The Swain Turbine.*—The Swain turbine is a mixed flow wheel, inward and downward, of which a sectional view is shown in Fig. 45, and an external view with vertical shaft in Fig. 44. *W*, Fig. 45, is the wheel, *A* the guides which are secured to the gate *G*, and are raised and lowered with it, and pass into and out of the chamber *E*. By this arrangement the inner ends of the guides are brought nearer the buckets than when the gate is between the bucket and guides, the space in this wheel being $1\frac{5}{8}$ inches. The gate is opened by being lowered, so that the water first enters just under the crown, and passing inward and downward is discharged nearly radially, while that which enters lower is discharged nearly axially. The guides and upper ends of the buckets are shown in Fig. 46. There are three heavy cast-iron guides, one of which is shown in Fig. 46, through which pass the lifting rods, as shown at *e*. The other 21 guides were 0.23 inch thick of bronze, sharpened at the ends to 0.04 of an inch thick, nearly 19 inches long. It had 25 buckets of bronze, pressed into shape and cast

into a crown above and band below, and were 23.35 inches deep. The gate G was made of two cylinders M and N, joined by a disc, Q. At the lower end of M is a narrow flange, to which was attached a leather packing to prevent the escape of water. The leakage was so small as to be unimportant. The wheel rested on an oak pivot, S, conical at its ends, free to turn or rest, and supplied with water through the pipe f. It was so arranged between the connecting piece a and crown V, that the step S could be replaced by another, and the adjustment of the height of the wheel made by means of the screws t, t. Opposite the thick vanes are stationary supports, of which one is shown at O, Fig. 45, resting on the cast-iron base C, and support the chamber E and cover of the wheel L. The openings in the base C for the passage of water into the wheel pit flow outward, as shown in the right-hand part of the figure.

An elaborate report of the test of this turbine—designed to replace the centre-vent turbine established in 1849 at the Boott Cotton Mills, previously described—is given by Francis and published in the *Journal of the Franklin Institute* for April, 1875, to which we are, through the courtesy of the Swain Manufacturing Co., indebted for the facts and tables herein given. Table XXIII. contains only the best result for each gate opening up to "full gate." Mr. Francis states that Table XXIV. is made from a curve of the results plotted on section paper.

It will be seen that the highest efficiency was obtained with the gate closed, 1.08 inches. This indicates that there may have been interferences of the stream of water in the bucket at full gate opening. It is also worthy of special note that the efficiencies are well maintained down to the smallest opening of 2 inches. The hydraulic efficiency for the best test was about 85 or 86 per cent.

DIMENSIONS.

Outer diameter, ...	$2r_1 = 6$ ft.
Least inner diameter, ...	$2r_2 = 2\frac{2}{3}$ ft.

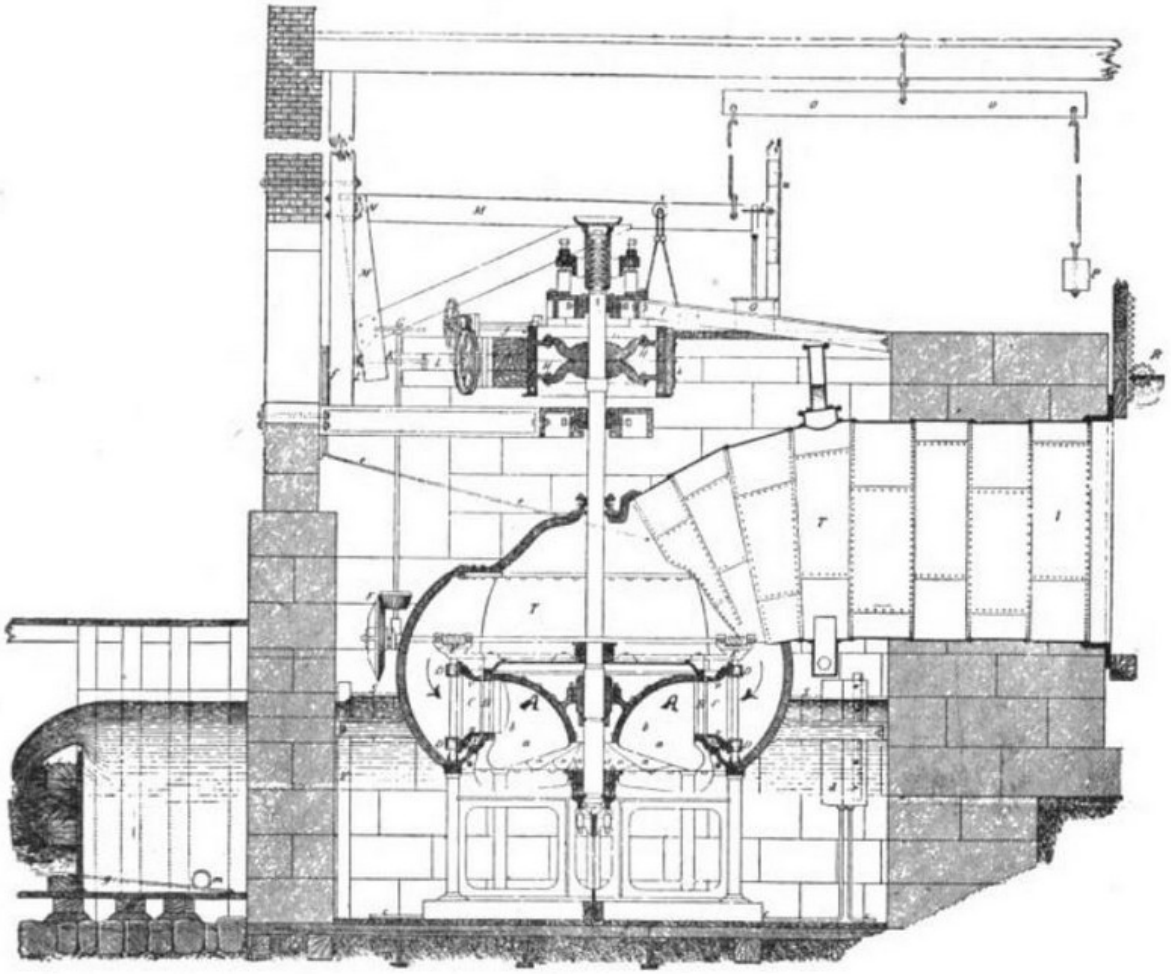


FIG. 42.

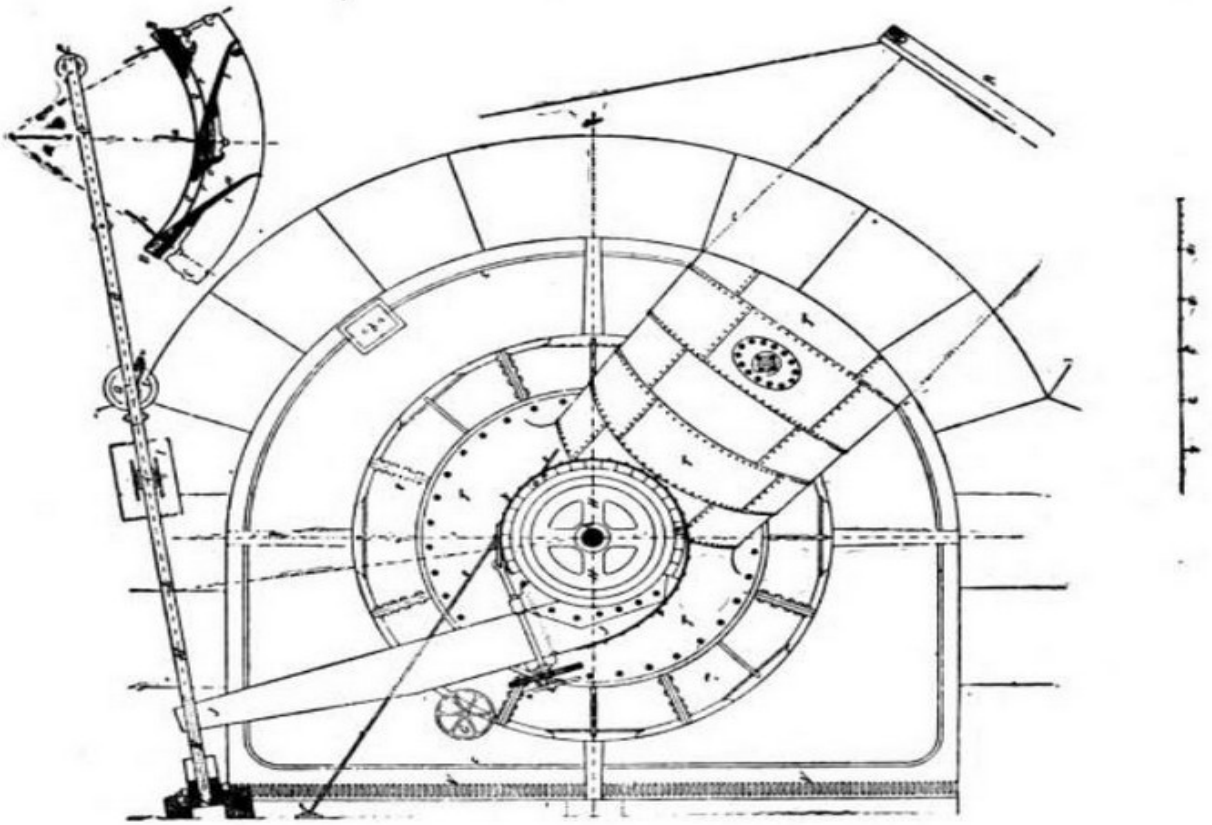
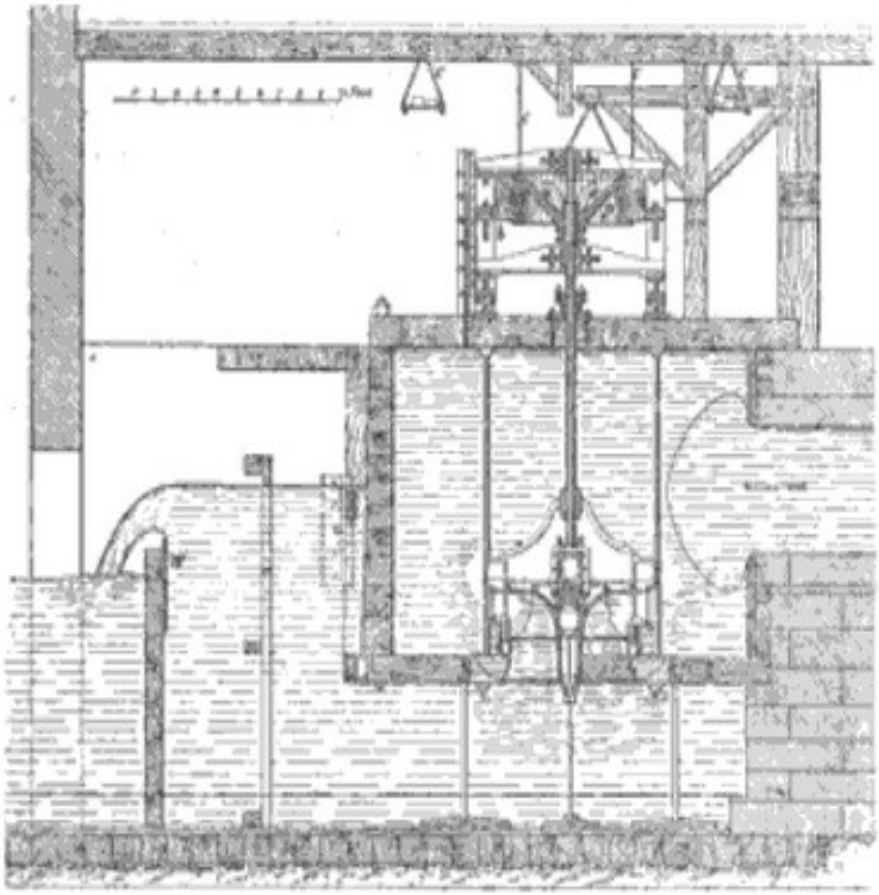


FIG. 43.



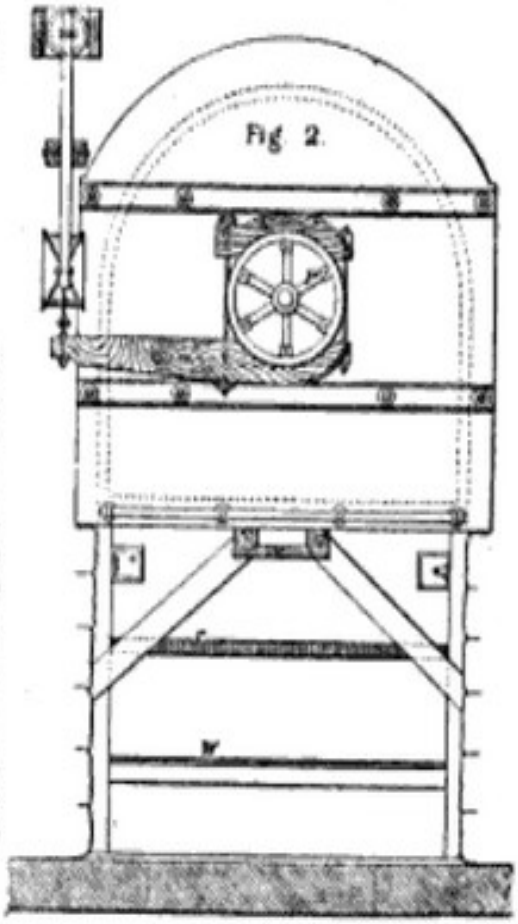


Fig 2.

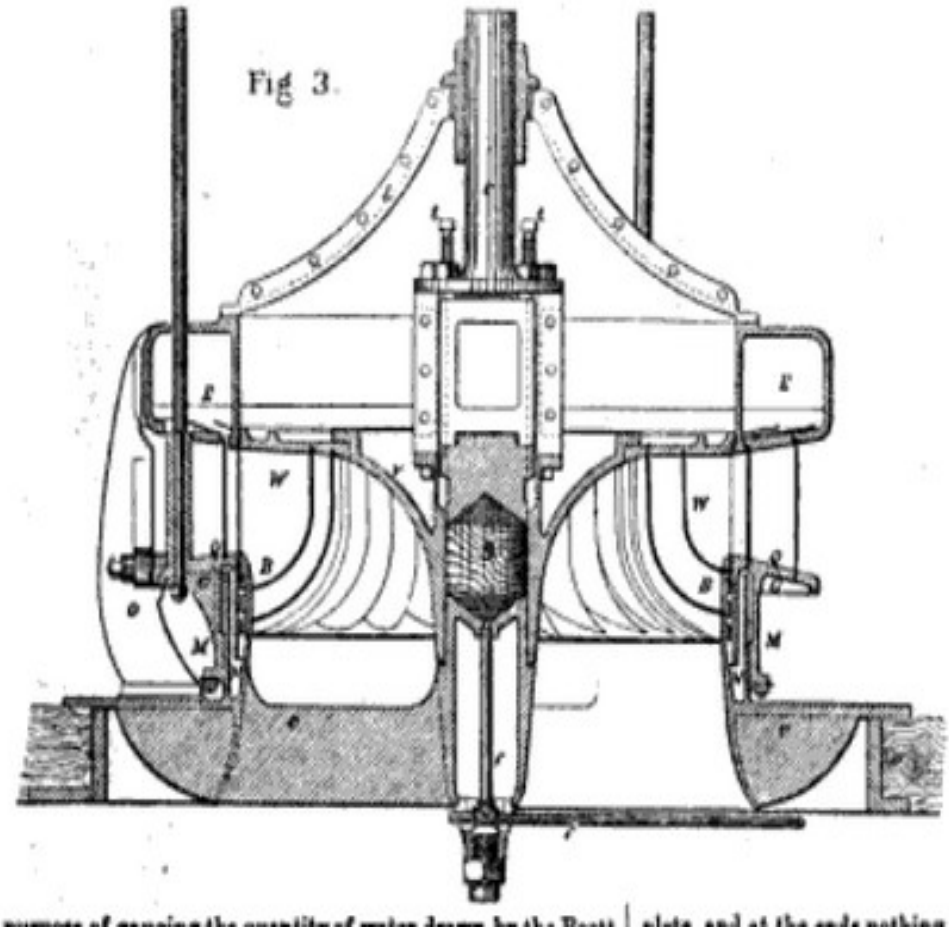


Fig 3.

Fig 4.

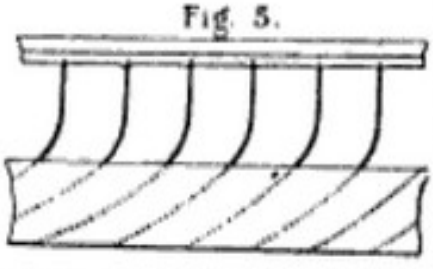


Fig. 5.